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June 21, 2017

VIA ELECTRONIC FILING

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Written *Ex Parte* Presentation

GN Docket No. 14-177, *Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*

Dear Ms. Dortch:

In its recent *ex parte* letter,[1/] The Boeing Company ("Boeing") proposes that the Commission:

- remove the prohibition on the operation of satellite end user terminals;
- define the conditions under which satellites are permitted to increase their transmit PFD levels to -105 dBW/m^2/MHz; and
- adopt equivalent power flux density ("EPFD") as the measure of satellite downlink interference to UMFUS in the 39 GHz band.

Straight Path urges the Commission to reject these proposals. The rules adopted in this proceeding strike the proper balance between the primary objective of enabling Fifth Generation ("5G") mobile wireless services in the 28, 37, and 39 GHz bands while still allowing *limited* use of these bands by the Fixed Satellite Service ("FSS"). Boeing's request is a significant departure from that primary objective. It will greatly impair 5G system performance and discourage investment in, and jeopardize the economic viability of, 5G services in the 37/39 GHz bands.

[1/] *See* Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.* (filed May 15, 2017) ("Boeing May *Ex Parte*").

Allowing Unlimited Satellite Customer Premises Equipment ("CPE") in the 37/39 GHz Bands, Even on a Secondary Basis, Will Significantly Increase Interference to 5G Services

Boeing is incorrect that there is no interference created by satellite CPEs because they are not transmitting in the 37/39 GHz band. When satellite CPEs are receiving, satellites are transmitting. Allowing an unlimited number of satellite CPEs can cause all satellites that serve the United States to transmit at the PFD limit all the time, causing significant interference to 5G deployments throughout the country.

The Commission has long adopted a "soft segmentation" approach in the V-band, in which the terrestrial service is designated the primary service in the 37.5 – 40 GHz band and FSS is designated the primary service in the 40 – 42 GHz band.[2/] FSS use of the 37.5 – 40 GHz band is limited by the following three requirements:

1. PFD is limited to -117 dBW/m^2/MHz on the surface of earth;
2. deployment is limited to gateway stations only; and
3. terrestrial licenses are required for gateway stations.

The first two requirements effectively limited FSS use of the 37/39 GHz band to a small number of gateway stations, allowing this band to be primarily designated for terrestrial services. Since the number of gateway stations would be small, the FSS downlink interference would only impact a small portion of 5G users nationwide.

The third requirement went further and required FSS operators to acquire terrestrial licenses for gateway stations. In response to the Notice of Proposed Rulemaking in this proceeding, satellite operators argued that they could not compete with terrestrial operators in an auction for terrestrial licenses.[3/] This claim alone demonstrates that satellite broadband cannot

[2/] *See Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations*, Second Report and Order, 18 FCC Rcd 25428, ¶ 24 (2003) ("*V-Band Second Report and Order*").

[3/] *See, e.g.*, Comments of The Boeing Company, GN Docket No. 14-177 *et al.*, at 8 (filed Jan. 28, 2016) ("[A]n auction approach would preclude the use of the 37 and 39 GHz bands for broadband satellite services given their wide geographic coverage and would effectively ignore the inherent intra-service sharing capabilities of these advanced FSS systems."); Comments of Satellite Industry Association, GN Docket No. 14-177 *et al.*, at 15 (filed Jan. 28, 2016) ("To prevail in an auction . . . an FSS operator would have to bid a market-clearing price for an entire county to protect an earth station that would affect only a tiny portion of the licensed area. If the earth station is located near the border of several counties, the FSS operator would conceivably have to secure winning bids for two or more licenses. While in theory FSS operators could attempt to recoup some of their bids by selling partitions to terrestrial operators on a secondary spectrum market, in practice this mechanism would be too unreliable to depend upon, and too costly to be practical or efficient."); Comments of O3b Limited, GN Docket No. 14-177 *et al.*, at 18 (filed Jan. 28, 2016) ("Pre-defined geographic areas of any size are unworkable for FSS, particularly if the only assured path to access is to acquire those licenses via auction.").

generate the same level of economic value using the same spectrum as mobile broadband. Due to its inherently high cost and limited number of satellites, satellite broadband can only achieve spectrum utilization much lower than that of mobile broadband. Straight Path's analysis shows that satellite broadband is ~100,000 times less efficient in spectrum utilization than 5G.[4/] As a result, despite of the vast amount of spectrum that has already been allocated for satellite use,[5/] satellite communications only accounts for 4% of the global telecommunications revenue and provides 180 times fewer connections than mobile broadband in the United States.[6/] Nevertheless, the Commission relaxed the requirement on terrestrial licenses for gateway stations, allowing up to 3 gateway stations per partial economic area ("PEA") without terrestrial licenses to facilitate the *limited* usage of this band by FSS.

This relaxation does not mean that there are going to be FSS gateway stations in every PEA. In the 39 GHz band, the Commission observed that "satellite operators will not necessarily need to deploy 39 GHz earth stations in the smaller, more densely populated PEAs."[7/] In fact, the number of gateway stations for FSS systems is generally small. For example, O3b has 9 gateway stations worldwide with 2 of them located in the United States.[8/] ViaSat-1 has 16 gateway stations in the United States.[9/] EchoStar XIX has 17 gateway stations.[10/] OneWeb is expected to have approximately 50 gateway stations worldwide.[11/] The restriction on earth station type is therefore crucial to limit the FSS downlink interference to a small number of areas where FSS gateway stations will be located. As satellite spot beam technology improves, the interference will be further reduced. For example, Boeing claims it will use spot beams with

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4/ *See* Comments of Straight Path Communications Inc., GN Docket No. 140177, *et al.*, at 27-30 (filed Jan. 27, 2016).

5/ *See* Letter from Davidi Jonas, CEO and President, Straight Path Communications, Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177, *et al.*, at Appendix (filed July 7, 2016) ("A total of more than 16 gigahertz of spectrum [in 10 – 60 GHz] is already available for satellite services"); *see also* Letter from Scott K. Bergmann, Vice President, Regulatory Affairs, CTIA, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177, *et al.*, at 1 (filed May 25, 2017) ("[T]here is 3.85 gigahertz of spectrum available to terrestrial wireless as compared to 16.5 gigahertz of spectrum available to satellite systems.").

6/ *See* Reply Comments of Straight Path Communications Inc., GN Docket No. 14-177, *et al.*, at 3-7 (filed Oct. 31, 2016).

7/ *See Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, et al.*, Report and Order and Further Notice of Proposed Rulemaking, 31 FCC Rcd 8014, ¶ 93 (rel. July 14, 2016).

8/ *See* Comments of O3b Limited, GN Docket No. 14-177, *et al.*, at 3 (filed Jan. 28, 2016).

9/ *See, e.g.*, ViaSat Inc., Application for Earth Station Authorizations, FCC International Bureau Presentation, File No. SES-LIC-20110418-00474 (filed Aug. 4, 2011) at 10.

10/ *See* Letter from Jennifer A. Manner, Senior Vice President, Regulatory Affairs, EchoStar Corporation, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al*., at 4 (filed May 5, 2017).

11/ *See, e.g.*, WorldVu Satellites Limited, Application for Satellite Space Station Authorizations, OneWeb Non-Geostationary Satellite System, File No. SES-LIC-20110418-00474 (filed Apr. 28, 2016) at 6.

radii as small as 8 kilometers.[12/] If accurate, the 5G users impacted by FSS downlink interference will be small for a limited number of gateway stations.

Allowing satellite CPE in the 37/39 GHz bands will significantly increase the amount of traffic carried in the 39 GHz space-to-earth link. In a typical satellite broadband system with a "bent pipe" architecture,[13/] the forward link consists of an uplink (gateway ➔ satellite) and a downlink (satellite ➔ CPE). The return link also consists of an uplink (CPE ➔ satellite) and a downlink (satellite ➔ gateway). For broadband access, the forward link versus return link traffic ratio can be as high as 12:1.[14/] Current rules permit the downlink in the 37/39 GHz bands to only carry the return traffic (satellite ➔ gateway). Allowing satellite CPE in this band will allow forward link (satellite ➔ CPE) traffic in this band, which can increase the traffic volume by ~12x. Because video will account for an increasingly higher percentage of traffic on 5G systems, this asymmetry will only become higher over time.[15/] Additionally, because satellite CPE typically has 10 – 30 dB less antenna gain than gateway stations, a satellite will need to use 5~10x more time frequency resources for each bit transmitted to a CPE than that for a bit transmitted to a gateway station. Altogether, the increased traffic and the increased time frequency resources required per bit cause the effective interference to 5G to increase by ~100x.

Even in permitting sharing of the V-band between fixed services ("FS") and FSS, the Commission took a pragmatic approach to avoid high-density deployments of FS and FSS in the same band.[16/] 5G services will have much greater deployment density and a much larger variety of deployment scenarios than fixed terrestrial services. There is no precedent, nor evidence, that high density mobile services and high density FSS deployments can coexist in the same band.

In spectrum where satellite operations have primary access, satellite companies have long argued against sharing spectrum between mobile and satellite services. For example, satellite companies objected to sharing the 3.4 – 4.2 GHz band between FSS downlink and "terrestrial wireless applications such as WiMAX and future mobile services"[17/] In a recent filing, Intelsat

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12/ *See* Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, at Attachment (filed Mar. 31, 2017).

13/ *See A Practical Introductory Guide on Using Satellite Technology for Communications*, INTELSAT, at 2, http://www.intelsat.com/wp-content/uploads/2013/01/5941-SatellitePrimer-2010.pdf (last visited June 6, 2017).

14/ *See* Mike Dano, *On Path to Gigabit LTE, Sprint Moving Download/Upload Configuration to 3-1 to Support 12-1 Traffic Ratio*, FIERCEWIRELESS (May 16, 2017, 2:55 PM), http://www.fiercewireless.com/tech/path-to-gigabit-lte-sprint-moving-upload-download-configuration-closer-to-12-1-traffic-ratio.

15/ *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021*, CISCO, http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html (last updated Mar. 28, 2017).

16/ *See V-band Second Report & Order*, ¶ 23-29.

17/ *See Field Test Report WiMAX Frequency Sharing with FSS Earth Stations*, Satellite Users Interference Reduction Group, http://www.apt.int/sites/default/files/Rep-5_6E1WiMAX_Field_Test_Report_by_SUIRG.pdf (last visited June 21, 2017).

opposes the use of the 12.2 – 12.7 GHz band for mobile broadband on the ground that this band is already "filled with literally millions of unregistered receive-only earth terminals that inherently are incompatible with a terrestrial mobile service."[18/] Boeing, as well as many other companies, repeatedly called for exclusive access to the 40 – 42 GHz band for FSS.[19/] The claim that high density deployments of both satellite and mobile terminals are acceptable in bands primarily for terrestrial services but the same type of deployments are not acceptable in bands primarily for satellite services is simply not credible.

The rules in both segments of the V-band must be technically consistent. If high density deployment of 5G services and high density deployment of FSS can coexist, they should coexist in both segments of the V-band. If not, the Commission should continue the "soft segmentation" paradigm to ensure the success of 5G and FSS in their respective primarily designated bands. In contrast, Boeing contradicts itself by taking opposite positions in the two segments of the V-band with respect to sharing. On the one hand, Boeing claims not only a limited number of gateway stations, but also an unlimited wide deployment of satellite CPEs can coexist with nationwide 5G deployment in the 37/39 GHz bands. On the other hand, in multiple filings Boeing claims FSS must have exclusive access to the 40 – 42 GHz band.[20/] These two opposite claims are technically irreconcilable.

The Commission Should Not Specify a Trigger to Increase Ground PFD Limits

Straight Path does not oppose the satellite industry's request regarding transmitter power control *as long as the satellite PFD on the surface of earth stays below the -117 dBW/m^2/MHz limit*. To accommodate 5G services for drones, the surface of earth should include the space up to 400 feet above ground.[21/]

18/ *See* Opposition to Petition for Rulemaking to Permit MVDDS Use of the 12.2-12.7 GHz Band for Two-Way Mobile Broadband Service of Intelsat, at 3 (filed June 3, 2016).

19/ *See, e.g.*, Reply Comments of O3b Limited, GN Docket No. 14-177 *et al.*, at 11 (filed Oct. 31, 2016) ("The 40 GHz Band was not identified as a candidate for UMFUS in the Further Notice and the Commission should disregard calls for it to be reallocated or redesignated."); Reply Comments of ViaSat, Inc., GN Docket No. 14-177 *et al.*, at 11 (filed Oct. 31, 2016) ("[M]aintaining primary access for satellite in the 40-42 GHz and 48.2-50.2 GHz band segments is critical to providing the certainty needed for existing business plans."); Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, Attachment at 8 (filed Oct. 11, 2016) ("Broadband forward links to end users require: full access to 40.0-42.0 GHz band.").

20/ *See, e.g.*, Petition for Reconsideration of The Boeing Company GN Docket No. 14-177 *et al.*, at 22 (filed Dec. 14, 2016) ("Boeing's system will need access to a full five gigahertz of downlink spectrum, including full access to the 40.0-42.0 GHz band."); Comments of The Boeing Company, GN Docket No. 14-177 *et al.*, at 11 (filed Sept. 30, 2016) ("Boeing's NGSO system will need access to a full 5 GHz of downlink spectrum, including full access to the 40.0-42.0 GHz band.").

21/ *See FAA Doubles "Blanket" Altitude for Many UAS Flights*, FAA, https://www.faa.gov/news/updates/?newsId=85264 (last modified Mar. 29, 2016).

The satellite industry has been unable to demonstrate the ability to properly adjust the satellite transmission power to combat rain fade *without increasing the PFD on the surface of earth*. Due to their own technological limitations, satellite operators must set the transmission power according to clear sky condition. However, the rules do not mandate such an approach. Instead, the industry takes this path because it is unable to increase transmission power beyond the settings according to clear sky condition without exceeding the -117 dBW/m^2/MHz on the surface of earth.

There are at least two possible approaches for technology advancement to combat rain fade without increasing the ground PFD. First, the satellite industry can continue to shrink the size of its spot beams to reduce the coverage area per beam. As the spot beams get smaller, it becomes more likely that the entire coverage area of a spot beam will come under the same or similar rain fade condition, thus allowing more opportunities for the satellite transmitters to increase transmission power to compensate for rain fade without exceeding the ground PFD limit. As Boeing claims, satellites to be deployed in the V-band can produce spot beams with radii as small as 8 kilometers.[22/] If true, there should be ample instances where the same or similar rain fade is experienced within the coverage area of a spot beam with an 8-km radius (200 km^2 area). In those cases, satellite transmitters can increase transmission power to compensate for rain fade for that spot beam without exceeding the -117 dBW/m^2/MHz PFD limit. The satellite industry must also develop technologies to accurately measure rain fade within the coverage area of a spot beam and leave an adequate power margin so that the PFD on the surface of earth does not exceed the PFD limit. Secondly, the satellite industry can develop more sophisticated transmitters and receivers that can capture the increased channel capacity during rain fade without increasing the transmission power.[23/] These two approaches are not exclusive. Combined, it is possible for the satellite-to-gateway downlinks to enjoy *increased* capacity during rain fade without needing to exceed the PFD limit on the surface of earth.

Without the satellite industry demonstrating that there exists credible technologies that can increase transmission power without exceeding the ground PFD limit, the Commission should not set a trigger condition for satellite transmitters to exceed the PFD limit that penalizes 5G services due to the satellite industry's inability to properly combat rain fade.

Satellite interference at the current PFD level already creates non-negligible interference to 5G services in the 37/39 GHz bands. In previous filings, Straight Path provided

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[22/] *See* Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, at Attachment (filed Mar. 31, 2017).

[23/] *See* Yong-Ping Zhang, *et al.*, *Rainfall Effect on the Performance of Millimeter-Wave MIMO Systems*, 14 IEEE Transactions on Wireless Communications 4857, 4858 (2015). In the paper, the authors observe that "[o]n the one hand, absorption always degrades system performance by reducing the power gain of the wireless channel. On the other hand, a large number of rain drops in free space cause significant scattering in the mmW MIMO channel, which can be exploited to obtain multiplexing gain. When the rainfall is light, although the power of the channel matrix is degraded by absorption, the available multiplexing gain dominates the rainfall effect, and hence the channel capacity increases from light rainfall."

comprehensive analyses of the impact of satellite interference to 5G systems in the 37/39 GHz band.[24/] To summarize those analyses, a single satellite transmitting at the current PFD limit of -117 dBW/m^2/MHz can cause:

- up to 2 dB rise over the noise floor, if satellite interference impinges directly upon 5G BS receivers with the broadside of antenna panels pointing at horizon;
- up to a 0.75 dB rise over the noise floor, if satellite interference is reflected by typical roofs with 8 dB reflection loss and then impinges upon 5G BS receivers at low elevation angle; and
- up to a 3.5 dB rise over the noise floor at 5G BS receivers, if satellite interference is reflected by metal roofs with no loss and then impinges upon 5G BS receivers at low elevation angle.

Roof reflection alone in urban areas can increase the noise floor at 5G base station receivers by more than 0.5 dB more than 0.1% of the time in areas with more than 100 residential houses per km^2. The probability increases proportionally to the residential house density, the number of satellites transmitting, and the increased spatial utilization / MIMO order of 5G services.

The impact of a 12-dB boosted PFD can cripple 5G base station receivers in many cases. A single satellite transmitting at the current PFD limit of -105 dBW/m^2/MHz can cause:

- up to an 11 dB rise over the noise floor, if satellite interference impinges directly upon 5G BS receivers with the broadside of antenna panels pointing at horizon;
- up to a 6 dB rise over the noise floor at 5G BS receivers, if satellite interference is reflected by typical roofs with 8 dB reflection loss and then impinges upon 5G BS receivers at low elevation angle; and
- up to a 13 dB rise over the noise floor, if satellite interference is reflected by metal roofs with no loss and then impinges upon 5G BS receivers at low elevation angle.

Roof reflection alone in urban areas can increase the noise floor at 5G base station receivers by more than 0.5 dB more than 0.4% of the time in areas with more than 100 residential houses per km^2. The probability increases proportionally to the residential house density, the number of satellites transmitting, and the increased spatial utilization / MIMO order of 5G services.

This set of data is only for 5G base station receivers with a 16×16 element antenna array and the broadside of the antenna panel pointing horizontally. Satellite interference with -117 dBW/m^2/MHz PFD will have much more significant impact to deployments such as in-ground

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[24/] *See* Letter from Davidi Jonas, President and CEO, Straight Path Communications Inc., and Jerry Pi, Chief Technology Officer, Straight Path Communications Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, at 2-10 (filed May 17, 2017) ("Straight Path May *Ex Parte*); *see also* Letter from Davidi Jonas, President and CEO, Straight Path Communications Inc., and Jerry Pi, Chief Technology Officer, Straight Path Communications Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, at 8, 20 (filed Dec. 20, 2016).

base stations with antenna array pointing directly upward,[25/] 5G services to drones that fly up to 400 feet above ground,[26/] and 5G networks by drones as airborne base stations.[27/] An increase of the PFD limit to -105 dBW/m^2/MHz PFD will generally disable such deployments and services for 5G.

Boeing's Simulation Study of Satellite Interference to 5G is Both Unrealistic and Incomplete

Boeing used Open Street Map building data in its simulation study of satellite interference to 5G.[28/] As Straight Path pointed out previously, Open Street Map building data are not appropriate in modeling reflection of satellite interference.[29/] In its later submission, however, Boeing did not cite the source of its building data.[30/] It is not clear whether such building data contain enough buildings or sufficient details of the buildings to properly model roof reflections of satellite signals.

Another major deficiency in Boeing's study is that the increased utilization of spectrum by massive multiple input, multiple output ("MIMO") techniques is not considered at all, resulting in very limited usage of the spectrum by 5G services. Much of the interference reduction in Boeing's simulation is achieved by assuming 5G devices are either transmitting or receiving using one high-gain beam at a time. That is not how 5G systems operate. In general, a 5G cell can utilize up to 50% of the spatial domain at any given time with the rest of the space used for interference suppression. For example, a 5G base station that covers 90° in azimuth and -30° ~ 30° in elevation can transmit (or receive) using 27 beams with 10° half power beam width in both elevation and azimuth. With 5° half power beamwidth in both elevation and azimuth, it can transmit (or receive) using 108 beams. This increased utilization of spectrum resources in space, which is a signature feature of 5G systems, is not modeled in Boeing's simulation study. By omitting this feature, Boeing's simulation results are at least an order of magnitude (*i.e.*, ~10x) too optimistic.

25/ *See Swisscom and Ericsson Plant LTE Small Cells Underground*, ERICSSON (Mar. 9, 2016), https://www.ericsson.com/en/news/2016/3/swisscom-and-ericsson-plant-lte-small-cells-underground; *see also Innovation Award for Kathrein Street Connect*, KATHREIN (Sept. 28, 2016), https://www.kathrein.com/en/newsroom/news/announcement/news/innovation-award-for-kathrein-street-connect/.

26/ *See* Monica Alleven, *Qualcomm Shares LTE Drone Trial Results*, FIERCEWIRELESS (May 4, 2017, 12:14 PM), http://www.fiercewireless.com/wireless/qualcomm-shares-lte-drone-trial-results.

27/ *See* David Nield, *Google Is Testing a Superfast 5G Network Powered by Drones*, TECHRADAR (Jan. 30, 2016), http://www.techradar.com/news/internet/google-is-testing-a-superfast-5g-network-powered-by-drones-1314082.

28/ *See* Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, Attachment 2 at 13 (filed Mar. 31, 2017).

29/ *See* Straight Path May *Ex Parte*, at 2-4.

30/ *See* Boeing May *Ex Parte*, Attachment 2 at 7.

Yet another major deficiency of Boeing's study is that the per-cell statistics are missing. The data provided by Boeing are averaged across multiple 5G cells, which conceal the percentage of cells that are greatly impacted. For example, assume 20% of the 5G cells have 5% of the users impacted by more than 0.5 dB. The overall statistics will only show 1% of the total users are impacted by more than 0.5 dB. However, in reality, the quality of service is already greatly degraded in 20% of the cells. As we proposed and as is generally accepted,[31/] the satellite interference should not cause interference more than 0.5 dB. Boeing's own simulation data show satellite interference exceeds the 0.5 dB threshold in about 1% of the links simulated (averaged across multiple cells). This is not acceptable for 5G operations. The coverage target for mobile operators is generally defined at 98 or 99 percent on a per-cell basis. It is untenable that satellite interference *alone* can cause 0.5 dB performance loss at the 99th percentile. Worse, as Boeing's own data shows, there is a significant percentage of 5G base stations that will suffer more than 1 dB of performance loss.

Instead, the satellite interference impact to 5G receivers should not exceed the 0.5 dB threshold in all cases. If any further relaxation is required due to the large variety of 5G deployment scenarios, it could be acceptable if the 99.5 percentile rise over noise floor caused by satellite interference exceeds 0.5 dB in no more than 1% of the 5G cells. In addition, other use cases, such as connectivity solutions for drones or using drones as airborne base stations, need to be investigated to understand the impact of satellite interference on such important future applications.

Equivalent Power Flux Density is Not an Appropriate Measure for Interference to Mobile Communication Systems

As Straight Path has argued, Equivalent Power Flux Density ("ePFD") is not an appropriate measure for satellite interference to 5G services.[32/] Boeing admits the ePFD approach assumes the 5G base stations and mobile stations have certain antenna configurations and only point the antennas towards a few directions.[33/] This assumption is fundamentally wrong for 5G systems. There will be a large variety of antenna configurations for both 5G base stations and mobile stations.

The diverse channel environments of 5G services also invalidate the assumption that satellite interference originating from a particular angle will stay at that angle. Many objects, natural or man-made, can turn satellite interference coming at a high angle into interference impinging horizontally at the victim receivers. Non-flat terrain, slopes, mountains, slanted roofs, slanted car windows and windshields – any non-vertical building surfaces, etc. – are all capable of such reflection. Boeing acknowledges that common roof materials cause strong reflections

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31/ *See* Straight Path May *Ex Parte*, at 7.

32/ *See* Reply Comments of Straight Path GN Docket No. 14-177 *et al.*, at 20-21 (filed Oct. 31, 2016).

33/ Comments of The Boeing Company, GN Docket No. 14-177 *et al.*, at 31 (filed Sept. 30, 2016); *see also* Boeing May *Ex Parte*, at 2.

with reflection loss ranging from -13 dB to 0 dB (average reflection loss -8 dB).[34/] Straight Path's analysis of satellite interference caused by roof reflection demonstrates the impact of those reflections on 5G receivers.[35/] As low earth orbit ("LEO") satellites orbit around the earth, the reflection directions change. With thousands of moving satellites and millions of randomly located and oriented reflectors, it is appropriate to measure the aggregated interference by summing the PFD from multiple satellites that are transmitting towards the same area, albeit at different angles.

Boeing argues that ePFD has been established as a metric for measuring satellite interference in other bands. However, the coexistence in these bands is only between FSS and FS. In those cases, fairly restrictive assumptions can be made for the dish antennas used in FS. And the high antenna gains of those dish antennas (40 – 60 dB gain typical) and the horizontal pointing directions greatly mitigate the chances of FSS signals interfering with FS systems. This fundamental basis for using ePFD as a measure of satellite interference does not exist in the 37/39 GHz bands for 5G services. The deployment of 5G devices can reach hundreds of millions, if not billions. The equipment used in the deployment of mobile systems are much more diverse and cannot be completely captured by a few restrictive models. It is possible for the satellite downlink to interfere with 5G devices at any angle. Therefore, the right measure of satellite interference is the aggregate PFD from all satellites transmitting in the same band and same area.

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The Commission should retain the rules adopted in the Report and Order in this proceeding and expedite the process of making the spectrum available for 5G services in the 28, 37, and 39 GHz bands. The Commission should also make the 40 – 42 GHz available for FSS satellite-to-CPE downlink and make the 37/39 GHz bands available for FSS satellite-to-gateway downlinks to meet the demands for satellite broadband. The Commission must reject the repeated requests to further expand satellite rights to use the 37/39 GHz bands to the detriment of the imminent 5G deployment in this band. Instead, the Commission should revisit this issue in a separate proceeding that focuses on sharing of the entire V-band, including how to increase utilization of the 37/39 GHz bands for FSS and how to increase utilization of the 40 – 42 GHz band for 5G services.

Pursuant to Section 1.106 of the Commission's rules, a copy of this letter has been filed in the record of the above referenced proceeding.

Respectfully submitted,

/s/ Davidi Jonas

[34/] Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, Attachment 2 at 11 (filed Mar. 31, 2017).

[35/] *See* Straight Path May *Ex Parte* at 2.

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